

CHANGES IN RECTAL AND CUTANEOUS TEMPERATURES DURING MUSCULAR
EXERCISE PERFORMED IN AIR TEMPERATURES BETWEEN 10° AND 30°C

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16. Abstract Students were subjected to large variations in ambient temperature while performing muscular exercise (pedalling machine). Rectal and cutaneous temperatures were measured. Slight effects were found for air temperatures below 5° C and above 30 °C.			
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CHANGES IN RECTAL AND CUTANEOUS TEMPERATURES DURING MUSCULAR EXERCISE PERFORMED IN AIR TEMPERATURES BETWEEN 10° AND 30°C

V. Candas, J.J. Vogt, & J.P. Libert*

I. INTRODUCTION

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Since the experiments of M. Nielsen (1938), it has classically been believed that core temperature in males during muscular exercise is proportional to energy expenditure independent of ambient thermal conditions. The independence of thermohygrometric conditions in this regard was described over a range of air temperatures from 5 to 30°C and a range of partial water vapor pressures from 5 to 20 mb. According to this writer, mean cutaneous temperature, which is directly related to environmental temperature, is not influenced by the level of metabolism. The observations by M. Nielsen were conformed in numerous works reviewed by B. Nielsen in 1969.

However, some qualifications of these conclusions have been presented by certain workers. According to Wyndham and collaborators (1967), the region in which central temperature is not influenced by ambient temperature varies with the state of acclimation and stamina at work. According to Lind (1963), this region of no influence is reduced in proportion to increases in mechanical power. Finally, Kitzing and colleagues (1966) as well as Wenzel (1969) have demonstrated that central temperature is directly influenced by ambient temperature.

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* With the assistance of A. Hoeft, collaborator at C.N.R.S.

** Numbers in the margin indicate pagination of original foreign text.

When energy expenditure is relatively small, rectal temperature can fall below resting temperature under cool conditions. We have confirmed these conclusions with an experimental procedure in which large variations in ambient temperature are imposed during continuous muscular exercise. According to the theory of M. Nielsen, such variations in air temperature should not affect the level of core temperature.

II. EXPERIMENTAL PROCEDURE

Two students served as subjects in the experiments. The experiments took place in the morning between 9:30 and 12:00 noon. After a rest period of 30 min. in a seated position at thermal neutrality (dry temperature = 28°C ; partial water vapor pressure = 8.5 mb. for a subject wearing shorts), the experiment itself began. It consisted of 3 phases of 40 minutes each.

The first phase included no variations, with dry temperature = 20°C and partial pressure of water vapor = 8.5 mb.

In the second phase, the ambient temperature was brought to 10, 15, 20, 25 or 30°C with the same hygrometry.

In the third, final phase, the dry temperature was maintained at a constant value fixed at the time of the second phase. For subject 1, the hygrometry was brought to 90 percent relative humidity. For subject 2, the third phase did not include any variation in environmental parameters.

During the 120 minute duration of the experiment, the subject pedaled continuously at powers of 67, 83 and 100 W; the speed of pedaling was always fixed at 60 rotations per minute.

We recorded the following variables each minute:

— Rectal temperature, measured at 10 cm in the rectum by means of a periodically calibrated pyrex probe with a platinum wire.

— 10 cutaneous temperatures measured by thermocouples. Binnert and co-workers (1973) have described the technical characteristics and the corrections to be applied to the measurements from these instruments. Calibration of these thermocouples before and after the experiments ensured precision of measurement. /A241 The mean cutaneous temperatures were calculated with coefficients of surface equilibrium (Hardy and Du Bois, 1938).

— The air temperature, regulated to $\pm 0.1^{\circ}\text{C}$, and the wall temperatures are also detected with thermocouples;

— The air humidity, regulated to $\pm 0.2^{\circ}\text{C}$ of dew temperature, was controlled by a detector at dew point.

III. RESULTS

In the present study, we were interested in simple variations of rectal and cutaneous temperature observed after changes in dry temperature, or, in other words, in body temperatures observed during phases 2 and 3 of our experimental procedure. /A242

We will distinguish between early variations which correspond to phase 2 of our procedures (between the 40th and 180th minutes of the experiment) and late variations which occur during phase 3 (between the 80th and 120th minute of pedaling).

Figure 1 represents early rectal temperatures observed between the 40th and 80th minutes of muscular exercise in the two subjects.

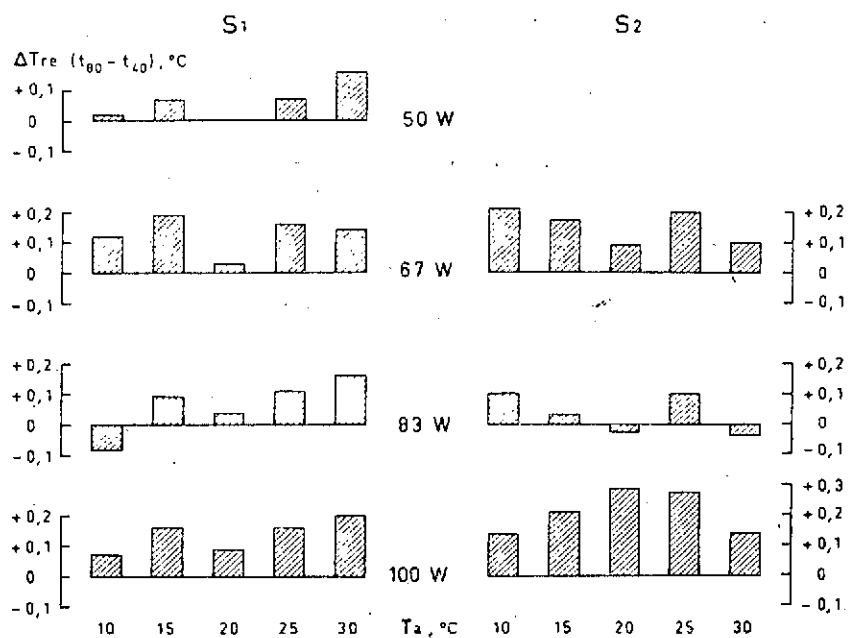


Figure 1. Magnitude of variations in rectal temperature observed from the 40th to the 80th minute of the experiment. This time segment corresponds to 40 consecutive minutes at the level of dry air temperature. This temperature level corresponds with a rapid passage from a dry temperature of 20°C to a temperature of 10, 15, 20, 25 or 30°C. The different levels were applied to subject S_1 during ergometric bicycle pedaling at powers of 50, 67, 83 and 100 W and to subject S_2 at powers of 67, 83 and 100 W.

For each mechanical power developed and for each air temperature used, we represented variations in rectal temperature on the ordinate. Subject 2 (at right in the figure) did not appear to be affected by the direction or magnitude of variations in ambient temperature during the first 40 consecutive minutes of the phase, since no simple systematic explanation accounts for the results.

For subject 1, at left, it is important to note that rectal temperature variations are small only when air temperature is maintained at 20°C. If this temperature varies, the tendency to increase is more marked for a positive step than for a negative step, with the exception of results for a power of 67 W.

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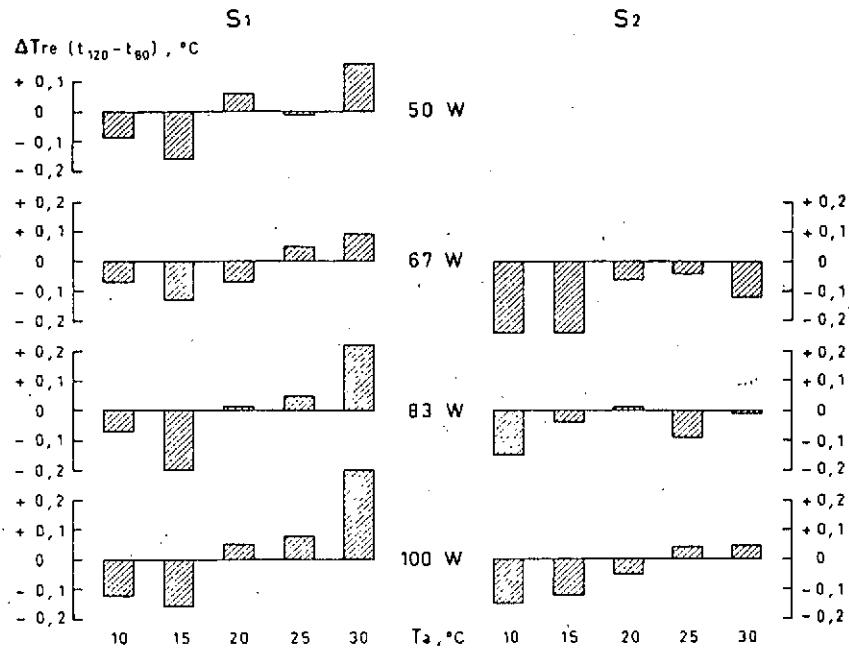


Figure 2. Magnitude of variations in rectal temperature observed from the 80th to the 120th minute of the experiment. This time segment follows the period incorporating the 40th to the 80th minutes at a level of ambient temperature (see legend for Figure 1).

Figure 2 represents later variations in rectal temperatures observed between the 80th and 120th minutes of pedaling for the two subjects. It appears as though the body temperature of subject S_2 is influenced over a longer period by ambient temperature. The more the air temperature is elevated, the greater are the late variations in body temperature in the sense of an increase or a smaller reduction in this subject. These variations are modulated by the intensity of muscular exercise. For example, at 30°C, the change in core temperature is negative for muscular exercise at 67 W, nil for muscular exercise at 83 W, and positive at 100 W. The same can be said for subject 1. It is appropriate, however, to recall that subject 1 underwent different degrees of humidity at the 80th minute. This change, however, exerts a marked influence only at an ambient temperature of 30°C because the humidity of the air then hinders evaporation of perspiration.

In any case, we can conclude that the rectal temperature does not show well-differentiated variations during the first 40 consecutive minutes at a temperature level such as that in our experimental procedures. On the other hand, over a longer period a clear tendency appears for rectal temperature to fall at air temperatures less than 20°C. This tendency is reduced or inverted for air temperatures over 20°C.

The early variations in mean cutaneous temperature, observed between the 40th and 80th minutes of pedaling, confirm the relationship between skin temperature and dry air temperature. Hardly any effect of energy expenditure on cutaneous temperature can be detected in our two subjects.

Figure 3 shows variations in mean cutaneous temperature observed between the 80th and 120th minutes of pedaling.

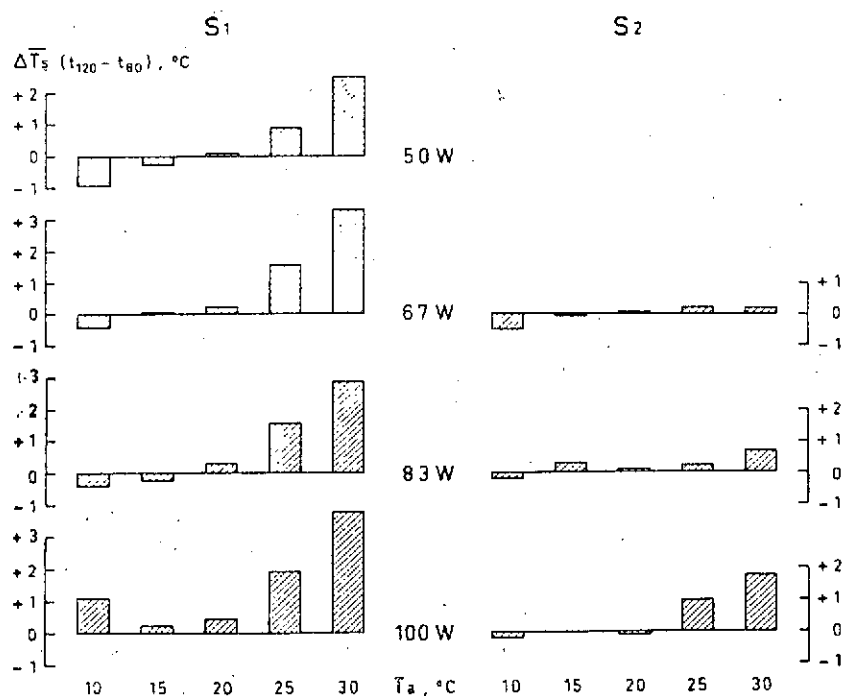


Figure 3. Magnitude of variation in mean cutaneous temperature observed from the 80th to the 120th minute of the experiment. This time segment follows the period between the 40th and 80th consecutive minutes at a level of ambient temperature (see Figure 1 legend).

For subject S_2 , the increase in cutaneous temperature observed at 25° and 30°C is greater when the mechanical power developed is higher. The effect of mechanical power developed on variations of cutaneous temperature is clear for subject S_1 . At 20, 25 and 30°C, the late increase in mean cutaneous temperature is more marked when the mechanical power developed is higher. At 10 and 15°C, a late increase in cutaneous temperature is observed when the mechanical power developed is 100 W, while for the other mechanical power intensities developed, the mean cutaneous temperature shows a late reduction. Compared to subject S_2 , these late variations show in addition an appreciable effect of air humidity. /A244

IV. DISCUSSION

From our results it appears as though ambient temperatures between 10 and 30°C influence core temperature, and that mean cutaneous temperature is altered by the level of metabolism. The variations are small but they exist. If it is necessary to use an experimental procedure like ours to show these variations, that is because this procedure allows the isolation of effects of variations in thermohygrometric conditions which differ from day to day. The effect of air temperature (between 10 and 30°C) is weak with respect to that of mechanical power developed; that is clearly because endogeneous thermal load is quantitatively much more important than exogeneous thermal load. However, the latter affects core temperature as energy expenditure and humidity affect cutaneous temperature. /A245

The use of our experimental procedure merits discussion. That thermal shock, even though small, temporarily alters the course of body temperature is not a surprising fact. It is consequently legitimate to ask if the variations in rectal temperature observed are not due to our experimental procedures. If

this were the case, it would be necessary to observe in response to the change in ambient temperature a detectable change in rectal temperature with a secondary return of rectal temperature to its previous value before the change. Our experimental results are diametrically opposed since it is only later (between the 80th and 120th minutes) that the variations in ambient temperature have more influence on the core temperature. It is during phase 3 of our experimental procedure that the between-condition differences in rectal temperature are largest.

V. CONCLUSIONS

The effects of air temperature on core temperature below 5°C and above 30°C are indisputable. Inside this range, a weak dependence of rectal temperature on ambient temperature appears more plausible to us than the total independence frequently claimed. The same is so with respect to sensitivity of cutaneous temperature to metabolism and air humidity. In fact, these interdependencies appear logical in the framework of an unitary conception of thermoregulation, valid for all thermohygrometric conditions and at all metabolic levels. On the other hand, the constancy of certain body temperatures would imply a discontinuity in the thermoregulatory process.

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